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The Environmental Effectiveness of the Beverage Sector in Norway in a Factor 10 Perspective

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Abstract

Scope and Background. The environmental effectiveness of the Norwegian beverage sector has been studied in a Factor 10 perspective. The objective of the study was to identify strategies that could make the beverage sector radically more effective from an environmental and resource perspective, leading to a Factor 10 improvement. Another main purpose of the work was to test the potential for using Life Cycle Assessment (LCA) methodology on an economic sector with a network of product chains, rather than for a single product.

Methods. Life Cycle Assessment data from STØ's own studies and literature studies have been used as a basis for analysis of the environmental status of the beverage sector in Norway. The functional unit was defined as the amount of beverage products consumed per capita in Norway in the year 2000. The study includes raw material production, production of the beverage product, packaging manufacture, distribution, use and waste management of the products. The study has, for practical reasons, been limited to the environmental impact indicators total energy consumption and global warming potential. This was done as other types of data have been difficult to obtain for all of the products that were studied (tap water, coffee, milk, soft drinks, beer, squash, juice and bottled water).

Results and Discussion. The study shows differences between the drinking products with respect to energy consumption and emissions that can contribute to global warming. Due to large uncertainties in the data, general conclusions regarding the differentiation of products based on environmental performance should be made with care. Production and distribution of tap water is, however, significantly less energy intensive than the other products. For the impact categories studied, production of raw materials was the most important part of the life cycle for most drinking products.

Conclusions and Perspectives. The most significant contributions to achieving a Factor 10 development can be made by consuming more water, especially tap water, and through improving raw material production in the agricultural sector. Packaging and distribution is responsible for only a small part of the energy consumption and emissions leading to global warming. Optimal packaging sizes might however reduce loss of products in the user phase, which is important in order to improve the system. A Factor 10 level seems achievable only if the consumption of tap water is increased to a high level.

Keywords: Beverage sector, Norway; environmental effectiveness; Factor 10 development; life cycle assessment (LCA); product chains, networks

Introduction

The Factor 10 approach has been introduced to make Sustainable Development more operational for society (Reijnders 1998, Hanssen et al. 2001, 2003). The background for Factor 10 development is a set of assumptions for 2050, or two generations:

– The global population is expected to increase by almost a factor of 2, from 6 billion in 2001 to 10-12 billion in 2050
– The global economy measured in Gross National Product (GNP) is expected to increase by at least a Factor 2,5, from about xx xxx per capita in 2000 to about xx xxx per capita in 2050
– Environmental stress should be reduced by a factor of 2, to 50% of the present level, e.g. 50% of the current level of emissions that have global warming potential.

These assumptions lead to the need for a Factor 10 improvement in environmental and resource efficiency and effectiveness for all activities in society, measured per economic unit, or per capita consumption (Hanssen et al. 2003).

A major project on Industrial Ecology was established in Norway in 1998 (Brattebø & Hanssen 1998). One part of this project focused on Factor 10 improvement in environmental and resource efficiency and effectiveness as a strategy for business development. The beverage sector was selected as a case study for several reasons:

– It was a sector where relevant companies were motivated to participate in the project work
– Statistics on historical market data were good, both for beverages and for packaging, which are important for estimating consumption and future market trends.
– Clean water for drinking is probably one of the most critical resources for human welfare globally.
– Food and liquids are relatively important parts of the total CO_2 emissions for a person's daily life, and are thus relevant in a Factor 10 perspective for environmental impacts (Rønning et al. 1999).

The main objective for this study has been to get an overview of the environmental impacts related to the whole Norwegian beverage sector as a network of product chains, as a basis for discussing how the sector can approach a Factor 10 improvement in environmental effectiveness.

Use of Life Cycle Assessment (LCA) as a tool for Sustainable Innovation has been described by Weaver et al. (2000), Hanssen et al. (2001) and Hanssen (2002), and has been used as a tool to analyse environmental and resource impacts of beverage systems.

1 Scope of the Study

The main scope of this paper has been to study environmental and resource efficiency and effectiveness for the beverage sector in Norway. This was to be used a basis for devising an approach in order to achieve a Factor 10 improvement in efficiency and effectiveness. In this paper, we present the results from a broad survey of the whole sector, based on a life cycle approach. The study was to establish a starting point for Factor 10 development in the sector and identify the most important aspects for improvement. In addition the study would provide input into developing strategies for improving environmental effectiveness.

2 Methodology and Data Sources

LCA methodology has been used as a basis for the study. Some adjustments have been necessary to accommodate the complex network of products to be studied. The idea behind the study has been to show the total environmental and resource impact of the beverage sector, based on the relative importance of the different products. An important aspect of the study has been to evaluate how environmental efficiency and effectiveness can be increased significantly within the sector. The study has considered which actors can contribute:

– actors within each of the product chains
– producers of beverages, making choices on which products to produce and sell, or
– the consumers, making choices between different beverage products in the market.

Efficiency, in this context, is defined as the technical efficiency of the system, i.e. how efficient the system is managed in order to produce and distribute a given unit of beverage products. Effectiveness is, on the other hand defined as a functional effectiveness, or how well the products fulfil the needs and requirements of given customers and users (see Hanssen 1999, Hanssen et al. in prep).

Due to lack of complete data for all relevant beverage products, the study has been limited to total energy consumption and climate gas emissions leading to global warming. Energy consumption includes all types of energy carriers, both renewable and non-renewable, as well as fossil and non-fossil energy carriers. Climate gas emissions include both CO_2 emissions, CH_4 emissions and other relevant types of emissions. Fossil energy consumption is a factor that often is well correlated with several environmental burdens, like climate gas emissions, acidification, nutriphication and photochemical smog formation. Energy consumption and in particular conversion of fossil energy carriers will thus often be a good indicator for many other types of environmental impacts of products (Hanssen 1998). Due to lack of data, the study has also been limited to those products where data are available with acceptable quality. This means that tea, spirits, wine and functional drinks have all been excluded from the environmental assessment part of this study, due to lack of data.

For the two environmental impact categories, two indicators have been selected to analyse the beverage sector over the total life cycle:

– impacts per litre of beverage products sold in Norway, and
– impacts per total volume of beverage products sold per capita in Norway in the year 2000.

The first indicator is mostly related to actors within the value chain and to the technical efficiency of the systems. The second indicator is related to both producers' strategies for marketing of beverage products, and to consumers' choices. The second indicator is more related to the Factor 10 approach (see part 1) and is also a measure of the functional effectiveness of the systems. With the given scope of the LCA study of the beverage sector, total volume of beverage product sold per capita has also been defined as the functional unit of the study, as the basis for calculating the reference flows of the different beverage products.

Market data for the per capita consumption of the different beverages and tap water in Norway in 2000 have been used to estimate reference flows for the study, based on statistics from the Norwegian Breweries and Beverage Organisation (BROM 2001). **Fig. 1** shows the volumes of the different products consumed. Tap water is the most important beverage (210 litres), followed by coffee (147 litres), milk (126 litres) and soft drinks (117 litres).

The Norwegian Refund organisation (Norsk Resirk), the organisation responsible for the Norwegian deposit system, has provided data for the use of different types of packaging for distribution of beverages in 2000. Data for milk packaging has been provided by the Norwegian dairy industry. Data for distribution and packaging of coffee and squash have been estimated based on average dilution factors given by producers. The two most important packaging types in the year 2000 were milk and juice cartons, and the refillable PET bottle (**Fig. 2**).

Data for consumption of beverage products, with their associated packaging systems, thus includes all products and producers in Norway in 2000, giving a representative picture of the total sector. A study of the whole beverage sector in a life cycle perspective is however difficult with respect to data availability and data quality. It was not possible to make specific LCAs for each type of beverage included in this study. This means that a number of different LCA studies and environmental reports have been used as data sources for the analyses (Vold 1994, Møller & Økstad 1995, Cederberg 1998, Johnsen 1997, Diers et al. 1999, Barkmann et al. 1999, Eide 2002a, b, Raadal et al. 2003, unpublished data from Fredrikstad and Bærum municipalities). Data for storage and final production of beverages (e.g. making of coffee and tea in the home) as well as data on packaging production, use and final waste management have been based on earlier studies by STØ (Møller & Økstad 1995, Johnsen 1997, Økstad et al. 1998, Ingebrigtsen 2002, Raadal et al. 2003). The data sources for each beverage product are shown in **Appendix 1**.

In order to achieve a Factor 10 level for energy converted for the beverages studied, it is estimated that total energy consumption per capita annual consumption of beverages must be reduced to 10% of the present level (Hanssen et al. 2003).

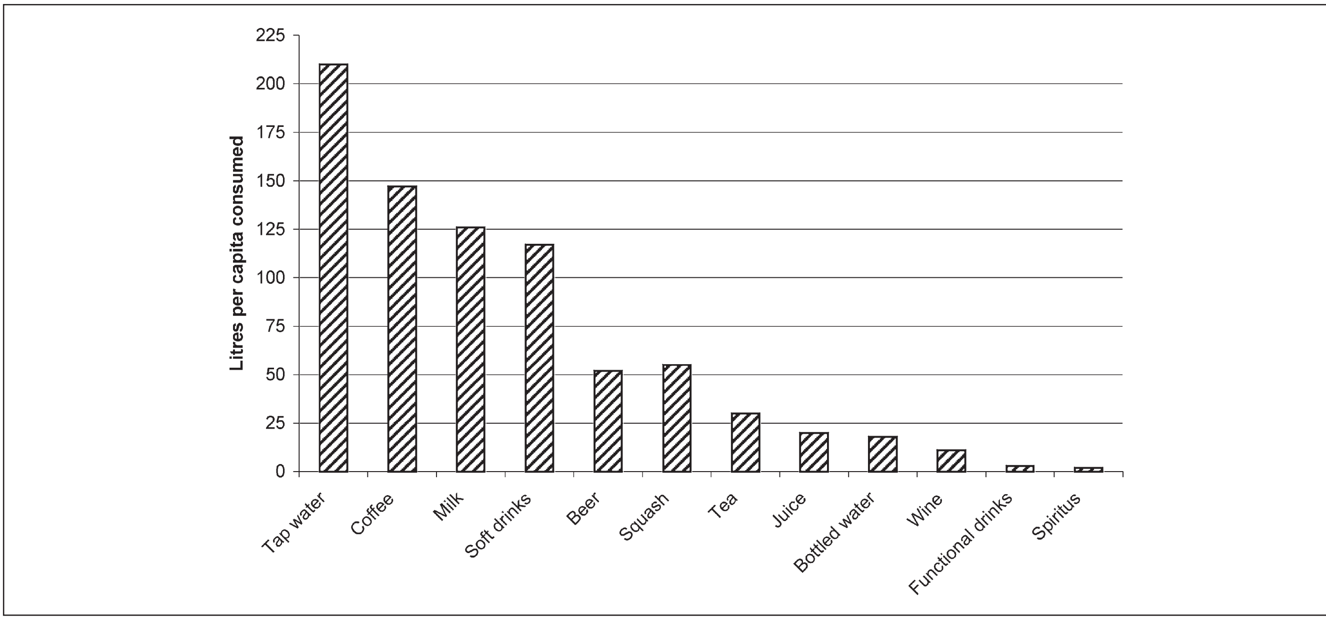

Fig. 1: Consumption of beverages in Norway in year 2000

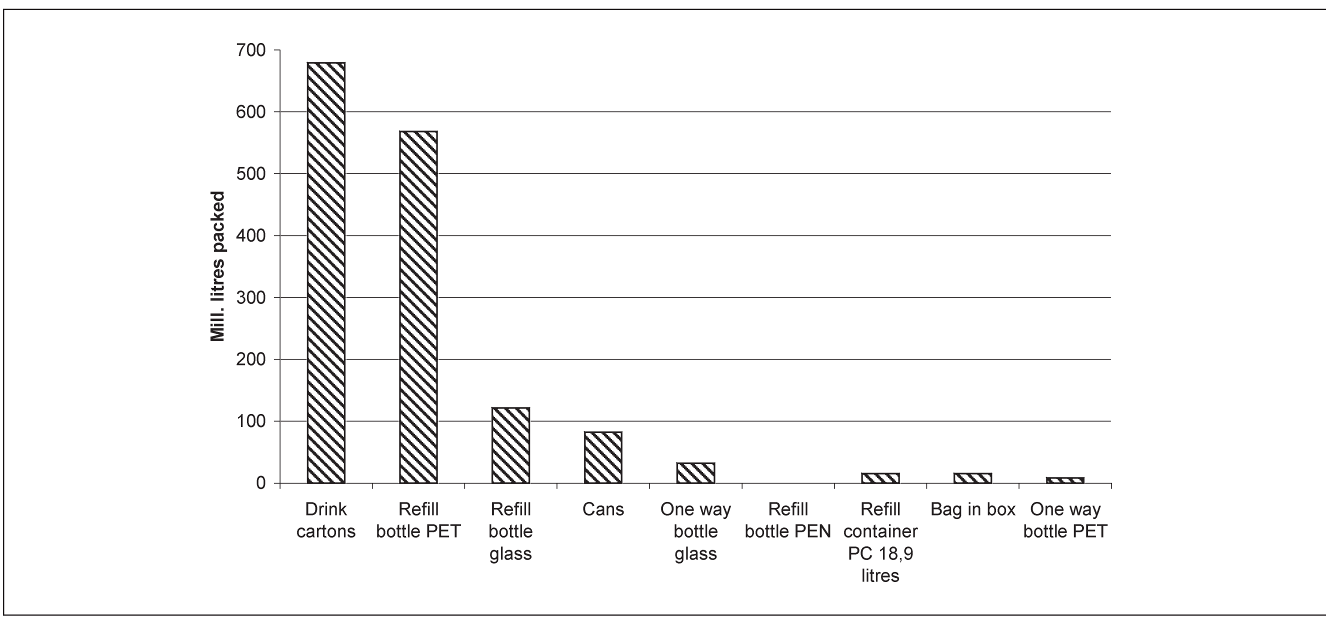

Fig. 2: Packaging of beverages in Norway in year 2000 (based on data from Norsk Resirk)

Three scenarios have been simulated to see if and how a Factor 10 level is possible to reach through changes in consumption patterns alone. It was assumed that no changes/improvements would be made in energy consumption for production or distribution of the products for all of the scenarios analysed. The assumptions for each scenario are presented in **Table 1.**

Table 1: Assumptions behind the different scenarios for Factor 10 development

Scenario	Water distribution	Other beverage products
Scenario A	Most water distributed as tap water – bottled water reduced to same level as other commercial products	All commercial beverage products reduced to a Factor 10 consumption level
Scenario B	All water distributed as tap water	Milk reduced to 90 litres per capita and year. All commercial products reduced to a Factor 4 level
Scenario C	All water distributed as bottled water	Milk reduced to 90 litres per capita and year. All other commercial products reduced to a Factor 4 level

3 Results

3.1 Energy consumption and global warming potential of beverage products

The results from the study are shown in **Figs. 3, 4**.

In **Fig 3a**, beer has a total energy consumption (MJ/litre) that is more than twice as large as the next most important beverages. Coffee, milk and juice are all more or less on the same level. The energy consumption of tap water is not shown in **Figs. 3a,b**, but is estimated to be about 0,0012 MJ/litre. This energy consumption is mainly related to electricity consumption in the treatment plant and for pumping of water. Raw material production and production of the beverages are the most important parts of the life cycle with respect to energy consumption. Production of plant nutrition for grass production (milk), sugar production (squash and other sweet beverages) and fermentation processes (beer) are all important in terms of energy consumption. When energy consumption is normalised to per capita annual consumption (see Fig. 3b), coffee, beer and milk become the most important products. There are, however, no large differences between these products. Squash seems to have the lowest energy consumption per litre of the commercial beverage products studied. The reason for this is that squash is distributed highly concentrated and mixed with an average of 80% tap water by consumers. The total amount of energy converted for beverage consumption in Norway in the year 2000 was about 1900 MJ per capita annual consumption of all beverages.

The results for global warming potential are shown in **Figs. 4a,b**. The relationships between the different products are quite different from those shown for energy consumption (see Figs. 3a,b). Milk is the most dominating product for global warming potential, with beer and squash second and third respectively (see Fig. 4a). The situation is even

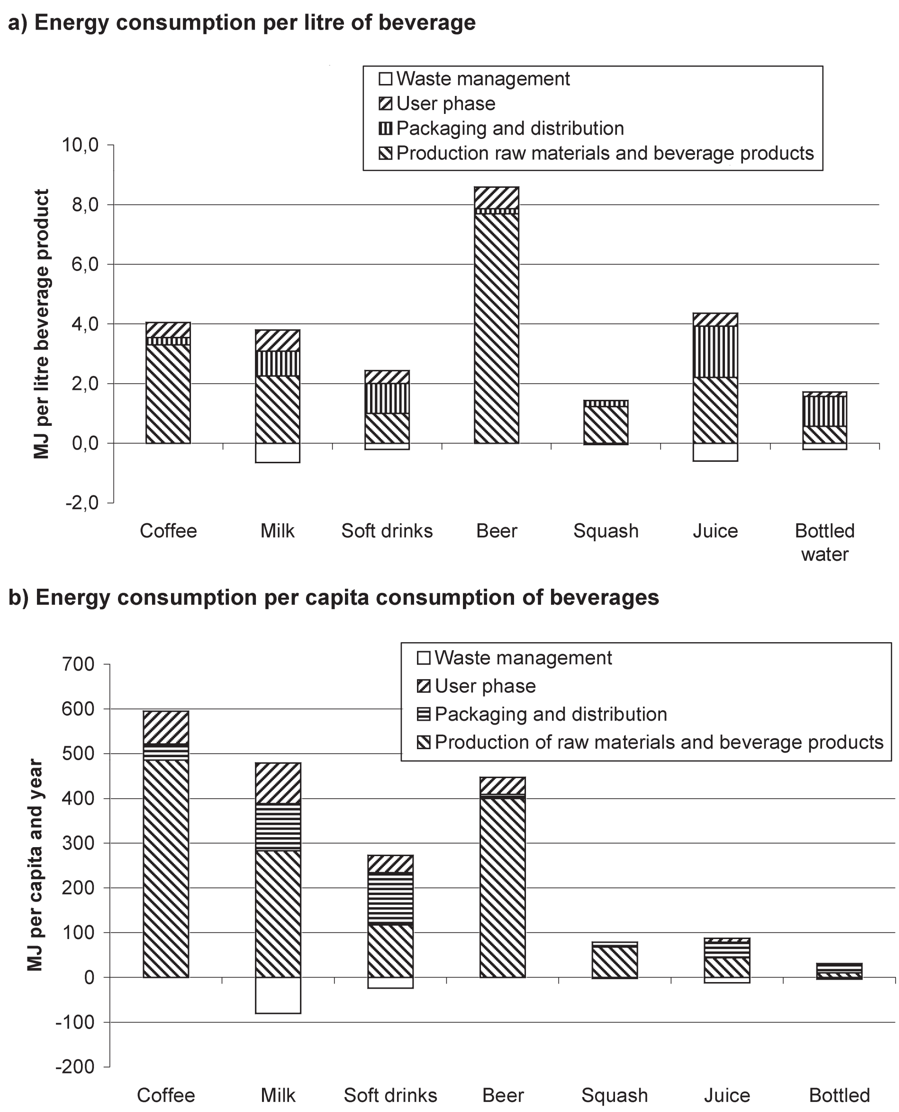

Fig. 3: Energy consumption per litre beverages (a) and per capita consumption of beverages per year (b)

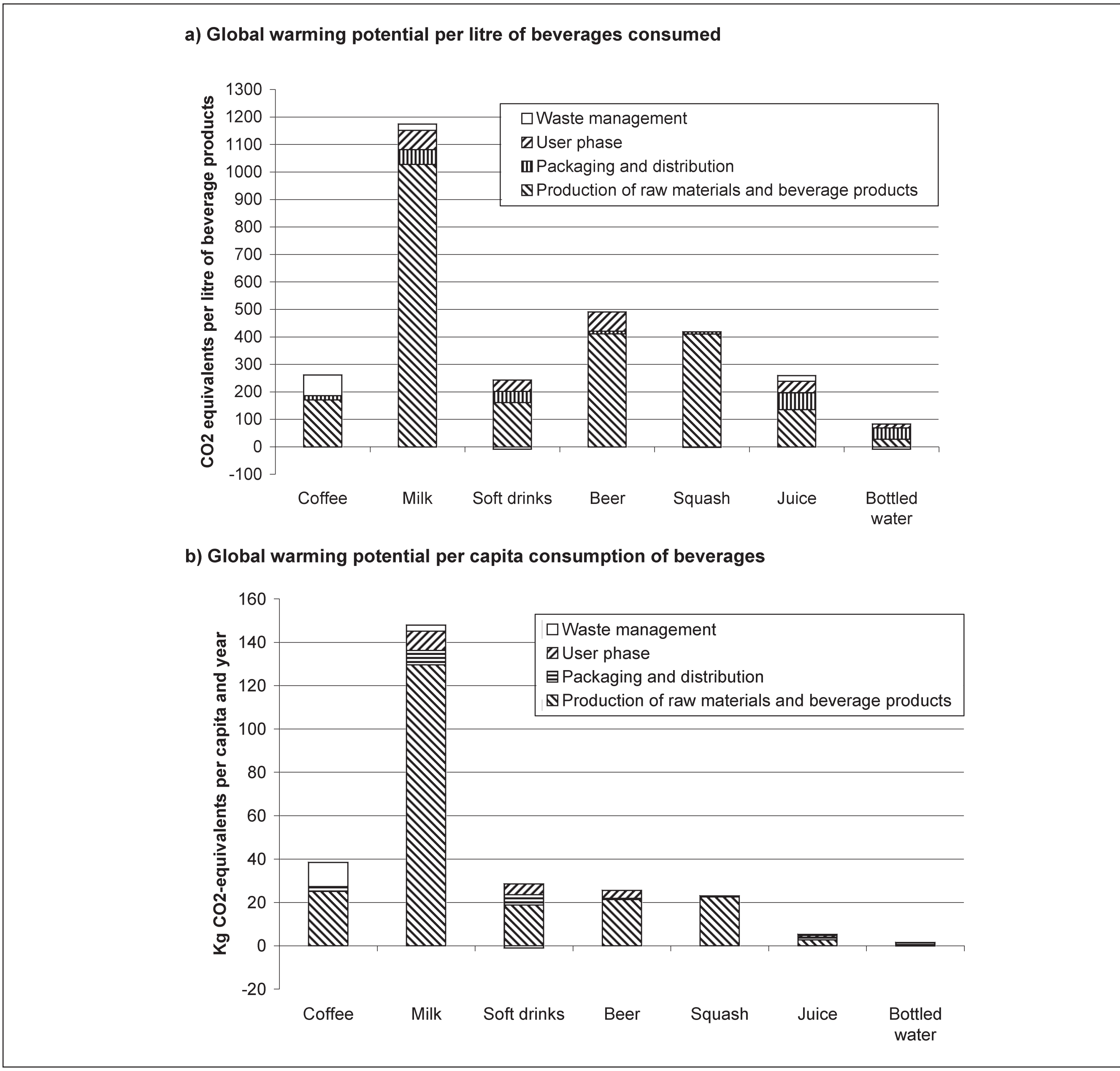

Fig. 4: Emissions of climate gases per litre beverages (a) and per capita consumption of beverages per year (b)

more different when considering the per capita consumption of beverages (see Fig. 4b). Milk shows results that are four times higher than the contribution to global warming for any of the other products. The global warming potential per capita consumption for milk is equal to the total sum of global warming potential for all of the other products. The main reason for this is that the global warming potential of milk is connected to agricultural activities, with high emissions of ammonia and methane from cows. For the other products, electricity is the main energy duty in production, distribution and the use phase. For these products, energy conversion is to a less extent coupled with climate gas emissions, as hydropower is the main energy carrier for electricity production in Norway.

3.2 Scenarios for Factor 10 environmental effectiveness

Based on the data in Fig. 3b, the amount of energy consumed should be reduced to about 190 MJ per capita total consumption of beverages in order to achieve a Factor 10 improvement in environmental and resource efficiency and effectiveness. It was assumed that tap water should be a substitute for other beverages in order to reach a Factor 10 level, as water is the drinking product with the lowest energy consumption per litre of product of those studied (see Fig. 3a).

Fig 5a shows the scenarios analysed in this study. In Scenario A the consumption of all beverage products, except tap water, is reduced to consumption level where a Factor

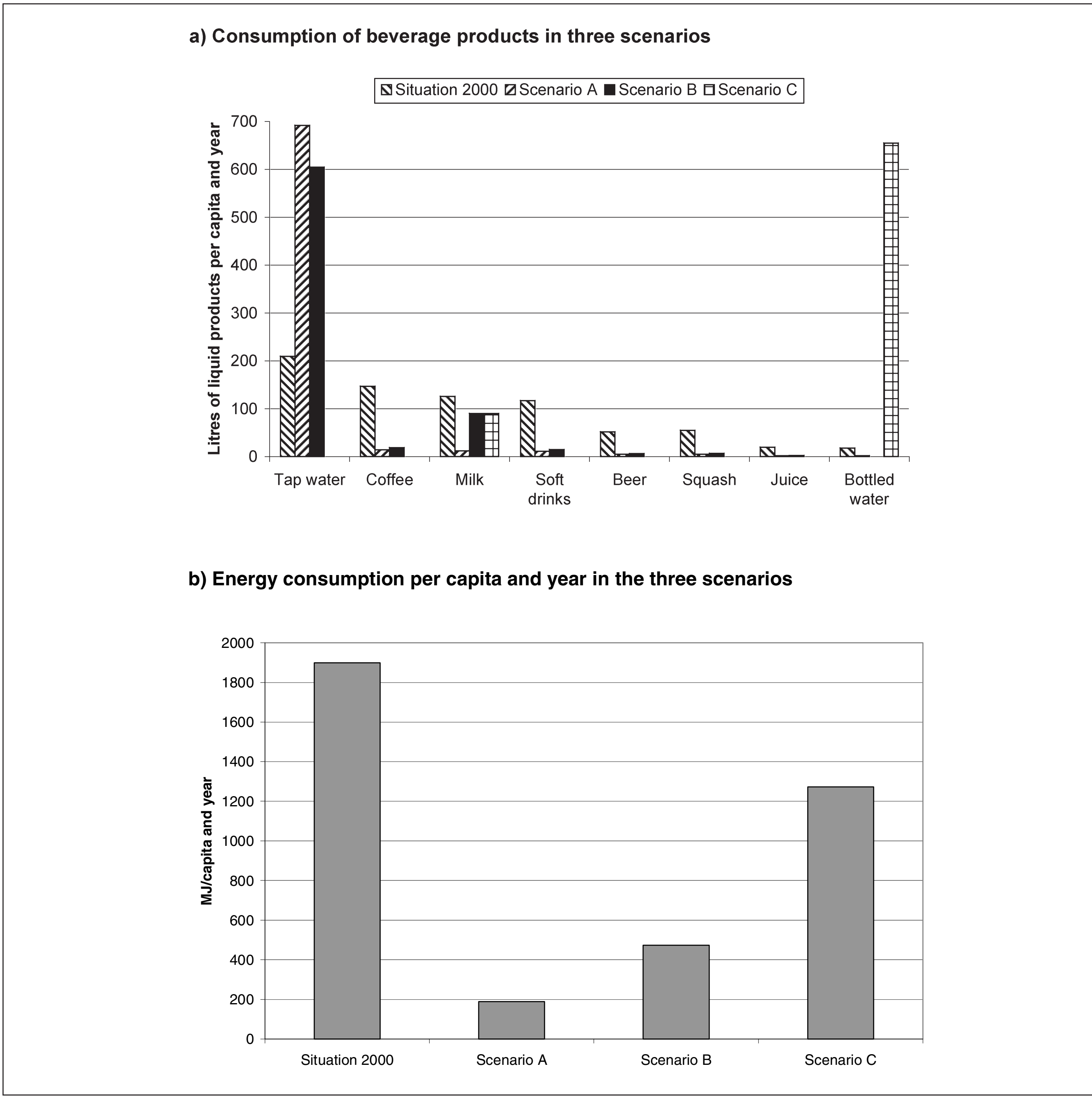

Fig. 5: Three scenarios for effects of changes in consumption patterns in the beverage sector. A: With 90% of other beverages than milk substituted with tap water. B: With all other beverages than milk substituted with bottled water. C: With all other beverages than milk substituted with tap water

10 level is achieved for energy consumption. In scenarios B and C it was assumed that milk consumption should only be reduced to 90 litres per capita consumption, due to the dietary need for minerals from milk. In Scenarios A and B, all water is distributed as tap water, with a very energy efficient distribution system. In Scenario C it was assumed that consumers would not accept the potential safety risks with tap water, and all water is distributed as bottled water.

The results of the simulations are shown in **Fig 5b**, where they are compared to the situation in the year 2000 (see Fig. 3b). The main results show that it is possible to reach a Factor 10 level if tap water is substituted for 90% of the volume of all other beverages, as was the case in Scenario A. A Factor 4 level is possible if the average consumption of milk is only reduced to 90 litres per capita and year, while the consumption of all other products is reduced to a level that is about 87% lower than the present situation (Scenario B). This means that more than 600 litres of tap water are consumed per capita in Scenario B and almost 700 litres in Scenario A (see Fig. 5a). If water is distributed as bottled water instead of tap water, as shown in Scenario C, it is not possible to reach even a Factor 2 level as long as the per

capita consumption of milk is 90 litres. The lowest possible level of energy converted is 1270 MJ, when all other products than milk are substituted with bottled water. Even if the restriction on milk consumption is relaxed and consumption of tap water is kept at 210 litres per capita, it is not possible to reach more than a Factor 5 level with bottled water substituting for the reduction of other beverages. Changing the consumption pattern alone is thus sufficient as a measure to reach a Factor 10 level, but the results of this for other beverage products would be dramatic.

4 Discussion

The present study is in many ways an untraditional LCA study, as the scope has been to study a broad network of different products in an economic sector that fulfils a complex utility function for consumers. The main idea behind the study has been to identify the most significant environmental aspects related to the total beverage sector, as a basis for developing a vision and strategies for achieving more sustainable solutions (Factor 10 beverage sector). The methodological basis for the project has been the Sustainable Technology Development project in the Netherlands (Weaver et al. 2000) and the Functional Industrial Network approach developed through the Factor 10 project in Norway (Hanssen 2002).

As the data in the study originate from a number of different LCA studies, and from a number of different institutes and countries, uncertainty is of course rather high. It is thus difficult to make comparisons between the environmental performances of the different beverages on a general basis. This uncertainty makes it difficult to reliably be able to recommend a preference for one product over another for environmental reasons. The only exception to this is tap water, where the energy consumption per litre of product produced is insignificant when compared to the other products. However, as discussed by Hanssen et al. (in prep.) this conclusion changes if the *functional effectiveness* of the tap water is taken into consideration. Only a very small amount of the tap water that is consumed needs to be drinking water quality. If treatment and distribution over long distances are allocated wholly to this small drinking water fraction, the energy consumption for tap water is approaching a level equivalent to bottled water (Hanssen et al. in prep.).

The findings in the study are in line with other studies, showing that, for environmental impacts, raw material production is the most important part of the life cycle for beverage products (Rydberg et al. 1995, Cederberg 1998, Diers et al. 1999, Barkman et al. 2000, Berlin 2002, Eide 2002a,b). A significant part of the energy consumption for the life cycle of beverage products is related to production of utilities for agricultural production, e.g. fertilisers, pesticides, etc.

When considering climate gas emissions, the results are even more dependant on raw material production. One important reason for this is that electricity used in the manufacturing, storing, cooling and cooking of most beverage products in Norway is based on hydro power, which has very low climate gas emissions (Vold et al 1998). This is however not the situation for all beverages, as some important sources of climate gas emissions and acid emissions are related to biological processes in agriculture (e.g. milk production in cows(Eide 2002a,b, Berlin 2002).

Packaging of the beverages is, in most cases, a very efficient system when compared to other distribution systems and packaging systems. Due to a well functioning refund system in Norway, more than 95% of all packaging for soft drinks, beer and squash are returned and reused, or recycled. The total impact of packaging in the beverage system is thus very low, as is the case in most other studies of packed products (Økstad et al. 1998). A study of the PET system in Norway showed recently that there were only minor differences between a returnable PET system and a one-way recyclable PET system (Raadal et al. 2003). For several environmental impacts, the one-way system had even better performance than the returnable system. Thus, in a Factor 10 perspective, it would seem that it is not a big problem if beverage sector packaging changes from returnable, reusable packaging to a one-way recyclable packaging system for health and safety reasons, economy and improved logistics.

For milk and juice packaging (beverage cartons), material recycling rates in Norway are still quite low (below 50%; Norwegian Carton Recycling Scheme Annual Report 2002). There is, therefore, still work to do to improve material efficiency in the distribution of these products. Increased material recycling and the use of recycled materials are the most important improvement options, where both plastic and fibre material should be recycled into new products.

One factor that has not been studied in detail in this project is the amount of product loss that relates to the different products and packaging systems. As the ratio between environmental performance of beverages and packaging for many products is about 1:10 or less (see Figs. 3,4), it is much more important to prevent product loss, than to minimise material use in packaging to a level where product loss might increase (Økstad et al. 1998). Prevention of spoilage of products by optimizing unit size in relation to consumer needs and user behaviour could thus be an important strategy in order to approach a Factor 10 improvement in the environmental and resource effectiveness of milk, beer, soft drinks and fruit juice (see Fig. 4). Coffee machines should also be optimized to produce the amount of products that is needed by the consumer. Packaging production is, on the other hand, relatively more important for products with low inherent energy consumption, especially bottled water.

The study has shown that it is possible to achieve a Factor 10 level in the beverage sector, and that this can be done through changes in consumption patterns alone. By substituting 90% of all other products with tap water, a factor 10 level in energy consumption is achieved. Consumers in Norway as in most other European countries seem to be more concerned about the health aspects of food and beverages, and the consumption of bottled mineral water has increased over the past years in Norway (BROM 2001). However,

substituting 90% of commercial beverage products with tap water is not a very realistic scenario, as needs other than purely physical needs will be important for the consumers (social, cultural, taste).

A combination of changes in consumption patterns, improvements in raw material production and production and distribution of beverage products will make a substantial improvement in the total environmental performance per capita and year. Sonesson & Berlin (2002) has shown that changes in consumption behaviour with respect to shopping and transport of food to the households are a key factor regarding milk distribution. In four different scenarios, both energy consumption and global warming might increase or decrease with 20%, depending on the scenario conditions. Eide (2002b) has also shown that energy consumption differ with a factor 4,5 between a small dairy and a large dairy due to scale factors. More centralised distribution systems might thus increase energy efficiency of the milk distribution.

Improving raw material production and especially agricultural production, is the most important factor. Two main strategies to be followed for such improvement are organic agriculture and 'smart agriculture' (Coghlan et al. 2002). Organic agriculture seems first of all to contribute to a Factor 10 level by reducing amount of toxic chemicals in plant production, whereas energy use and emissions to air and water is less influenced and might even increase (Cederberg 1998, Hanssen et al. 2003). However, Drake & Björklund (2002) has concluded that organic agriculture in general is preferred from environmental reasons.

'Smart agriculture' is also a possible strategy for improving the environmental performance of agricultural production (Coghlan et al. 2002). 'Smart agriculture' is more or less synonymous with cleaner production in the agricultural sector. Resources (e.g. water and energy) and toxic chemicals should be used at the lowest necessary level, by controlling and fulfilling the needs very carefully in each part of the production area. This can be regarded as a 'high tech' solution compared to organic agriculture, as sensors combined with computer modelling and information about local conditions in the area are used to optimise resource use. A combination of the two approaches might also be possible, although it is assumed that organic agriculture is more difficult to tune with respect to plant nutrients, as the nutrient content is not as stable as that found in industrial fertilisers (Coghlan et al. 2002). Technologies and conditions for a more resource efficient organic agriculture should be an important area in agricultural research in order to achieve more sustainable raw materials from agriculture.

5 Conclusions

This study shows that a Factor 10 level of environmental efficiency and effectiveness cannot be achieved in the beverage sector without a combination of radical shifts in consumption patterns and in production systems. Agricultural production is a key factor for achieving Factor 10. A Factor 10 level is achievable if tap water substitutes a large proportion of other beverages.

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Appendix

Table A1: References used in the studies of each of the beverage products

Beverage product	Raw material production	Production of beverage product	Packaging and distribution	User phase
Coffee	Diers et al. (1999)	Diers et al. (1999)	Diers et al. (1999)	Hanssen et al. (2001)
Milk	Eide (2002)	Eide (2002)	Johnsen (1997), Barkman (2000)	Eide (2002)
Soft drinks	Cederberg (1998) – data for suger	Vold et al. (1994)	Møller & Økstad (1995), Raadal et al. (2003)	Eide (2002) – estimated based in milk data
Beer	Cederberg (1998) – data for wheat	Vold et al. (1994)	Møller & Økstad (1995)	Eide (2002) – estimated based in milk data
Squash	Cederberg (1998) – data for suger	Hanssen et al. (2001)	Møller & Økstad (1995), Raadal et al. (2003)	Hanssen et al. (2001)
Juice	Barkman et al. (2000)	Barkman et al. (2000)	Barkman et al. (2000)	Eide (2002) – estimated based in milk data
Bottled water	Ingebrigtsen (2002)	Ingebrigtsen (2002)	Møller & Økstad (1995), Raadal et al. (2003)	Ingebrigtsen (2002)
Tap water	Hanssen et al. (2001), data from Fredrikstad and Baerum tap water distribution	Hanssen et al. (2001), data from Fredrikstad and Baerum tap water distribution	Hanssen et al. (2001), data from Fredrikstad and Baerum tap water distribution	Hanssen et al. (2001)

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Life Cycle Assessment (LCA) of Industrial Milk Production

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Abstract. A Life Cycle Assessment (LCA) was carried out for milk production extending from the origin of the inputs to the agricultural step to the consumer phase and the waste management of the packaging. Three Norwegian dairies of different sizes and degree of automation were studied. The main objectives were to find any hot spots in the life cycle of milk, to determine the significance of the dairy size and degree of automation, and to study the influence of transport. The agriculture was found to be the main hot spot for almost all the environmental themes studied, although the dairy processing, packaging, consumer phase and waste management were also of importance. The consumer phase was the main contributor to photo-oxidant formation and important regarding eutrophication. The small dairy was found to have a greater environmental impact than the middle-sized and the largest dairies. The transport did not have any major influence.

Keywords: Consumer; dairy; dairy processing; detergents; distribution; industrial milk production; LCA; life cycle assessment (LCA); milk; milk farming; milk packaging; milk production; packaging; transport; waste management